Positioning uncertainties for pediatric craniospinal irradiation and the impact of image guidance

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perform data normalization and in relevant cases digitally remove contrast agent from the bladder. Evaluation was performed on CT data from 18 prostate cancer patients, each with 7 to 10 repeat CT scans. Manual delineations of the prostate, lymph nodes, seminal vesicles, bladder and rectum were available for evaluation. Geometric performance was quantified using the Mean Surface Distance (MSD). The pipeline was validated dosimetrically on 11 out of 18 patients by simulating an online-adaptive PT workflow based on the propagated contours. To this end, for each repeat CT, a treatment plan was generated based on the propagated contours and the plan was evaluated using the manual delineations. A dose of 74 Gy was assigned to the high-dose PTV (prostate) and 55 Gy to the low-dose PTV (lymph nodes and seminal vesicles). The generated treatment plans were considered clinically acceptable if dosimetric coverage constraints derived from the manual contours were met (PTV $V_{95\%} \geq 98\%$ and $V_{107\%} \leq 2\%$).

Results

The proposed pipeline achieved a MSD of 1.29 ± 0.33, 1.44 ± 0.68, and 1.52 ± 0.45 mm for the prostate, seminal vesicles, and lymph nodes, respectively (Fig. 1). The propagated contours met the dose coverage constraints in 85%, 91%, and 99% of the cases for the prostate, seminal vesicles, and lymph nodes, respectively (Fig. 2). 78% of the cases met all constraints at the same time, compared to 65% when using a standard registration approach. The average runtime for the proposed pipeline is 98 seconds per registration.

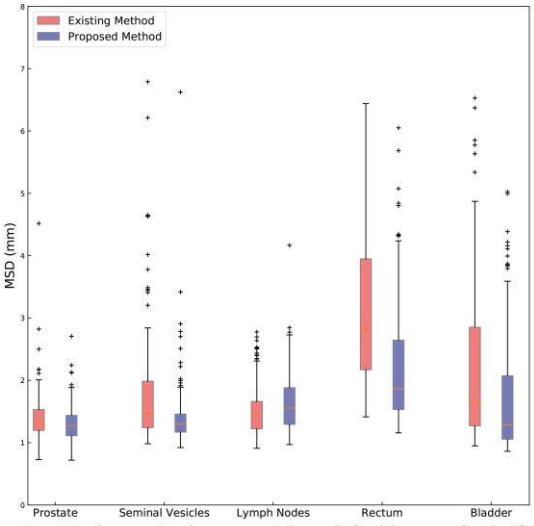

Figure1. Boxplot comparison between an existing method and the proposed method for image registration in terms of MSD for 161 registrations. Values closer to zero are better

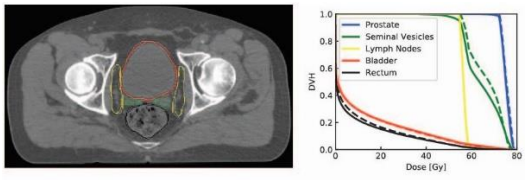

Figure 2. Example for the automatic contours propagation and the corresponding dose volume histograms. The solid line represents the manual contouring results while the dotted line is the automatically propagated one.

Conclusion

The proposed registration pipeline obtained highly promising results for generating treatment plans adapted to the daily anatomy. With 78% of the automatically generated treatment plans directly usable without manual correction, a substantial improvement in system robustness was reached compared to an existing approach. The proposed method therefore facilitates more precise PT of prostate cancer.

PO-0990 Positioning uncertainties for pediatric craniospinal irradiation and the impact of image guidance

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Purpose or Objective

To investigate the setup errors for pediatric craniospinal irradiation (CSI) by following image guided correction protocols and explore how daily image-guided radiotherapy (IGRT) has impacted the positioning uncertainty. In particular, we wish to determine the use of six degree of freedom (DoF) couch corrections. Positioning uncertainty data may be used to estimate the uncertainty budget available for planning target volumes and organ-at-risk (OAR) margins, which is essential for the safe clinical implementation of hippocampal-sparing CSI for pediatric medulloblastoma. Patient alignment and setup errors become paramount when attempting to spare a critical organ such as the hippocampus during CSI.

Material and Methods

In this multicenter study, a total of 14 pediatric patients treated with CSI were identified for whom treatment records and setup images were available. The setup images were registered offline to the reference image (digitally reconstructed from their pre-treatment computed tomography scan) using the automated tool and matching on bony anatomy. A 3 and 6 DoF match was performed, respectively, using both translational (superior-inferior (SI), anteroposterior (AP) and medial-lateral (ML)) and rotational (yaw = rotation around the AP axis, pitch = rotation around the ML axis and roll = rotation around the SI axis) information, ignoring the rotational deviation since only the 3 DoF couch shift was used for positioning these patients during treatment.

Results

The residual errors should only include rotational deviation since only translational movement on the couch is used. However, rotational errors can affect the translational deviation as well (Table 1). When correcting the shifts according to a simulated IGRT-protocol, where the average of the first two fractions are used to correct the coming fractions, the results show large inter-fractional deviations especially for rotational deviations (Figure 1). Translational and rotational random uncertainty (RU) and systematic uncertainty (SU) were derived as well. If using an IGRT-protocol, such as the above mentioned, the translational residual setup error can be as high as 2.2 cm for an individual patient during a single fraction, and the rotational error as high as 5.4 °. If using daily IGRT the maximum setup error was reduced to 0.8 cm translational and 5.4 ° rotational as well as 0.8 cm translational and 2.4 ° rotational setup error for 3 and 6 DoF couch shifts, respectively. The RU and SU of ML and roll worsens when only correcting for the first two fractions which further strengthens the indications for daily IGRT.

Table 1: Mean translational (superior-inferior (SI), anteroposterior (AP) and medial-lateral (ML)) and rotational positioning errors with corresponding range and uncertainties assuming setup based entirely on skin marks for both 3 and 6 degrees of freedom (DoF) and all isocenters (Units: cm and °/degrees).

3DoF	SI	Range	RU	AP	Range	RU	ML	Range	RU
Translational									
- Head	-0.08	(-1.0 - 2.2)	0.28	-0.20	(-1.1 - 1.0)	0.27	0.06	(-0.6 - 1.3)	0.21
- Thoracic	-0.07	(-0.9 - 2.4)	0.30	-0.04	(-0.9 - 0.8)	0.24	0.14	(-0.4 - 0.9)	0.21
- Lumbal	0.08	(-0.9 - 2.3)	0.29	0.27	(-0.8 - 2.1)	0.34	0.01	(-0.8 - 1.0)	0.27
6DoF	SI / Roll	Range	RU	AP / Yaw	Range	RU	ML / Pitch	Range	RU
Translational									
- Head	-0.10	(-0.9 - 2.2)	0.27	-0.19	(-1.3 - 1.0)	0.28	0.04	(-0.7 - 1.3)	0.30
- Thoracic	-0.07	(-0.9 - 2.4)	0.28	-0.08	(-0.9 - 0.8)	0.25	0.13	(-0.4 - 1.0)	0.29
- Lumbal	0.07	(-0.9 - 2.3)	0.29	0.27	(-0.8 - 2.0)	0.34	0.03	(-0.9 - 1.1)	0.33
Rotational									
- Head	0.03	(-2.5 - 2.7)	0.68	-0.04	(-1.9 - 3.6)	0.56	-0.38	(-5.4 - 3.8)	1.12
- Thoracic	0.02	(-3.6 - 2.0)	0.66	0.04	(-3.1 - 3.1)	0.40	0.68	(-0.8 - 3.7)	0.61
- Lumbal	-0.05	(-4.8 - 4.3)	0.60	0.00	(-2.1 - 3.3)	1.20	0.03	(-3.9 - 1.4)	0.66

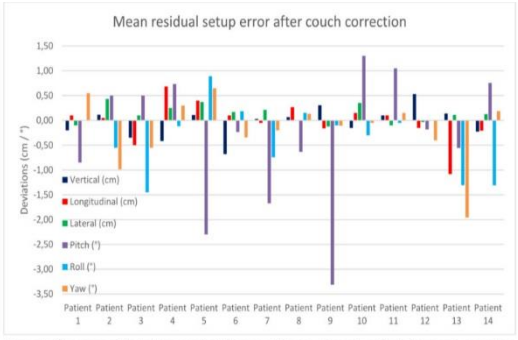

Figure 1: The mean residual setup error in 6 degrees of freedom for each patient after couch correction. Vertical describes the anteroposterior, longitudinal the superior-inferior and lateral the medial-lateral.

Conclusion

Daily IGRT is the superior choice for pediatric CSI patients. However, following an IGRT-protocol is no insurance for a satisfactory alignment when only a 3 DoF couch is applied. There are still quite large residual errors some of which are the result of multiple isocenters and narrow field junctions even if a 6 DoF couch shift would be applied.

PO-0991 A decision-support tool to select patients who may benefit from online adaptation in pancreatic SBRT

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Purpose or Objective

At our institution, patients with Locally Advanced Pancreatic cancer (LAPC) responding to chemotherapy undergo SBRT on the Cyberknife using respiratory tracking via fiducial markers. SBRT plans exhibit conformal dose distributions with high dose gradients, sculpted to the anatomy of the planning CT scan (pCT) to protect the surrounding organs-at-risk (OAR). These OARs (stomach, duodenum and bowel) are also prone to receive additional dose due to daily anatomical variations that can result in dose-constraints violations. In our previous work, we developed a population-based motion model, which using principal component analysis, extracted common geometric variation patterns from a cohort of LAPC patients. Based on this model, we developed a tool to identify which LAPC patients may be at risk of exceeding the clinical dose-constraint of V35Gy<1ml due to daily anatomical changes, and hence, that may benefit from online adaptive strategies.

Material and Methods

A total of 130 scans were collected for 35 LAPC patients, including the pCT scan and ideally 3 pre-fraction in-room CT scans (FxCT). The tool was validated by following a leave-one-out approach: each patient was tested on a model trained with the variations observed in the remaining 34 subjects. For each case, the OAR pCT contours were registered non-rigidly to the model, which was used to sample N (~5000) random OAR deformations. The pCT dose volume was sampled inside each simulated organ yielding DVHs for each OAR. Next, we collected which percentage of simulated OAR had been detected to exceed the clinical dose-constraints on each patient. To validate the tool performance against real observed variations, simulated violation percentages were clustered in four risk groups (low risk-0/3Fx; mid-low risk-1/3Fx; mid-high risk-2/3Fx; high risk-3/3Fx) according to how many fractions exceeded the V35 when original plans were rigidly transferred to the FxCT. A threshold on each OAR was established by optimizing the discrimination of patients with higher risks.

Results

Simulated violation percentages clustered per risk group are shown on Fig. 1. Pearson correlation coefficients of 0.5-0.8 were found between simulated risk and observed dosimetric changes, depending on the OAR. If all observed mid-high and high risk patient groups are combined into a high risk category, thresholds at 22, 57, 28% would maximally identify patients likely to violate OAR dose-constraints due to moving tissues for the simulated duodenums, stomachs and bowels; with a classification accuracy of 94, 71, 97%, respectively.

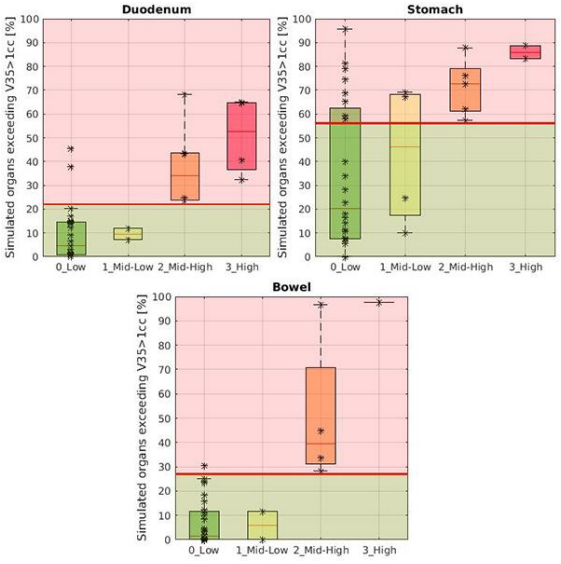

Figure 1. Percentage of simulated OARs exceeding the clinical dose-constraints (duodenum-upper left, stomach-upper right, bowel-bottom) clustered per risk group according to how many fractions resulted to exceed the dose-constraint in the clinic: 0/3 FxCT (low risk group), 1/3 FxCT (mid-low risk group), 2/3 FxCT(mid-high risk group), or 3/3 FxCT (high risk group). The thresholds established by the red horizontal line discriminate the patients (depicted in *) who would be identified as mid-high or high risk (in the red region), and hence, that would be eligible for plan adaptation; against patients classified in the low or mid-low risk groups (in the green region), which would be discarded from applying this strategy.

Conclusion

The positive relationship between the simulated probability of exceeding OAR dose tolerances and clinically observed dose-constraint violations is a promising tool to identify a high-risk patient suffering from the impact of daily variations. Established thresholds suggest patients can be stratified by making optimal use of available resources, and can prevent giving extra dose to low-risk patients not benefiting from plan adaptation.

PO-0992 Investigating 4D Cone Beam CT reconstruction for moving targets at a scanned proton gantry system

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